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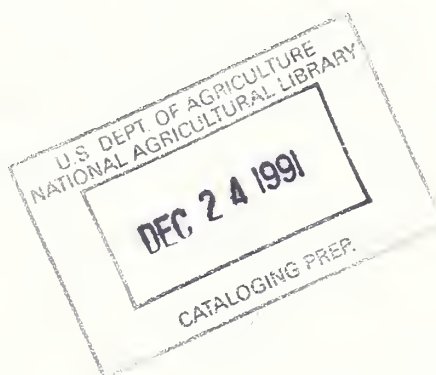
FINAL REPORT FOR MEMORANDUM OF AGREEMENT NO. 58-43YK-7-0028  
TITLED "EFFECTS OF PHOSPHORUS AND POTASSIUM ON TOBACCO  
CARBOHYDRATE PARTITIONING"

KY. AGR. EXP. STN. COOPERATOR - J. L. SIMS

USDA-ARS COOPERATORS - M.E. SALVUCCI

- S. J. CRAFTSBRANDER

USDA-ADODR - T.W. RUFTY



USDA, National Agricultural Library  
NAL Bldg  
10301 Baltimore Blvd  
Beltsville, MD 20705-2351

LET. S. A. 1981

## SUMMARY

## Phosphorus Nutrition

Phosphorus nutrition, and the subsequent levels of Pi and phosphorylated metabolites in the various cellular compartments, influences the partitioning of photosynthate within plant leaves. The objective of this study was to determine how P nutrition, ranging from severely deficient to supra-optimum P levels, affected tobacco growth and development and the partitioning of photosynthate within the entire canopy. Two Nicotiana tabacum L. cultivars (KY 14 and Speight G28) and a Nicotiana rustica L. cultivar, Pumila, were grown in the greenhouse in pots containing Zanesville silt loam soil. Rates of P fertilizer used were 0, 67, 134, 268, 536, 1072, and 2144 kg P ha<sup>-1</sup> for Pumila. The KY 14 and Speight G28 cultivars received the same amount of P pre-transplant and an additional equivalent amount near 4 weeks. Plants were harvested at 40 and 61 days after transplanting for Pumila and the N. tabacum genotypes, respectively. Plant growth, photosynthetic capacity, and total sugars in leaves of all cultivars increased as rate of P increased up to the 4th rate of P. No further increases occurred at rates above the 4th level. In contrast, concentration of P in leaves increased with rate of P up to the highest level of P. Sucrose: starch ratios in leaves were affected by rate of P but the effect



of P rate was not the same for all genotypes. As rate of P increased, the ratio increased in KY 14, decreased in Pumila, and remained nearly the same in Speight G28. These differences in ratios resulted from differences in the effects of P fertilizer on starch concentration rather than on sucrose concentration. Starch concentration increased with increased rate of P fertilization in Pumila and Speight G28 but had little or no effect on starch synthesis in KY 14.

#### Potassium Nutrition

An experiment was conducted in the field during 2 years at the University of Kentucky Spindletop farm on Maury silt loam soil. Ky 14 cultivar was transplanted into plots having previously been treated with varying rates and methods of application of K fertilizer. The primary thrust of the study was to look at rates of K fertilizer on growth and dry weight accumulation, K concentration, cured leaf yield and quality, photosynthetic capacity, carbohydrate partitioning between starch and sucrose, and the activity of the rate limiting enzymes in sucrose biosynthesis and CO<sub>2</sub> fixation. Rates of K used were 0, 140, 280, and 420 kg K ha<sup>1</sup>.

Ways to increase the efficiency of fertilizer use was of secondary interest. To do this, varying percentages of the soil surface were fertilized at each rate of K fertilization. The various percentage treatments were



established by placing K fertilizer in bands of varying width perpendicular to the direction of the tobacco rows creating fertilized and unfertilized soil zones to be compared with broadcast treatments. The percentages of soil surface fertilized (and the fertilizer incorporated) were 12.5, 25, 50 and 100% (broadcast).

Results for rate of K fertilizer averaged over percentage treatments indicated that (for both plants sampled at 40 days after transplanting and cured leaf) dry weight and K concentration and content increased as K rate increased up to 420 kg K ha<sup>-1</sup>. Cured leaf yield, price kg<sup>-1</sup>, and value ha<sup>-1</sup> were increased by only the first 140 kg K rate. Significant K rate x percentage surface soil fertilized interactions occurred for many parameters measured. Generally, these interactions suggested that values for dry weight, cured leaf yield, and dollar value ha<sup>-1</sup> were greatest when the lower K rates were applied broadcast or as a 50% treatment and when the high K (420 kg) rate was applied in the 12.5 and 25% treatments. In contrast highest values for K concentration and content generally occurred from broadcast applications of the 420 kg K rate. Price of cured leaf (\$ kg<sup>-1</sup>) generally was unaffected by placement methods.

Reasons for the interaction effects of rate and percentage treatments aren't known but likely at low rates of fertilizer the effects resulted from factors affecting



the efficient use of K by the plant, including the greater numbers of roots in contact with fertilizer in broadcast treatments. At high rates of fertilizer greater growth and yield in the narrow bands (12.5 and 25% treatments) may have resulted from (a) reductions in fertilizer salt injury during early growth stages and (b) to a more favorable balance between K and other nutrients in band treatments.

Potassium fertilization had only minor effects on partitioning of the non-structural carbohydrates starch and sucrose in plant samples taken during the time period between topping and harvest. However, the activity of the rate limiting enzyme in sucrose biosynthesis, sucrose phosphate synthase (SPS), increased as rate of K increased up to the 280 kg K rate. Similar K effects on activity of the rate limiting enzyme in CO<sub>2</sub> fixation, rubisco, were also noted. For both enzymes, the order of activity for K rate were 0 K < 140 K < 280 K = 420 K.



## INTRODUCTION

Starch synthesis in plants can be affected by the level of phosphorus (P) in the growth medium. While some plant species require a strict level of phosphate for maximal productivity, species such as soybean and tobacco exhibit optimal photosynthesis and productivity over a wide range of P concentrations. Recent studies with soybeans, spinach, and barley have shown that starch levels can be reduced two-fold and the sucrose/starch ratio increased concomitantly by increasing the internal inorganic phosphate ( $P_i$ ) concentration through phosphate fertilization. Although most of the excess phosphate is sequestered in the vacuole, higher levels must also occur in the cytosol and the chloroplasts in order to account for the observed effects on carbon partitioning.

Many of the reactions associated with photosynthetic carbon metabolism are heavily regulated. This regulation appears to be required in order to maintain homeostasis in the face of changing environmental conditions. Changing the phosphate status of the chloroplasts either by nutrition or through mannose-feeding can have little effect on photosynthesis but may drastically affect the level of starch synthesis. By altering the partitioning of carbon between starch and export for sucrose synthesis, metabolite levels in the chloroplast are maintained relatively constant under changing conditions. This regulation



appears to reside at the level of starch synthesis which indirectly affects the amount of fixed carbon available for export.

The rationale for the current phosphorus studies on tobacco is that by manipulating Pi levels, we should be able to exert an effect on carbohydrate partitioning while having no adverse effect on productivity. Altering the partitioning of carbon between sucrose and starch should modify the concentrations of other tobacco metabolites including health-related constituents which, depending on their intercellular site of synthesis, are formed from carbon stored as either sucrose or starch. Since regulation of starch synthesis occurs at ADP-glucose synthetase, a more complete understanding of the regulation of this enzyme, especially differences between genotypes, will enhance our understanding of starch synthesis and may suggest novel molecular approaches which could also be used to modify carbohydrate partitioning.

Our interest in K in these studies is the relationship between K deficiency and the accumulation of selected health-related carbohydrate constituents in burley tobacco. Numerous studies have demonstrated that K-deficient plants reduced growth, reduced rates of photosynthesis and translocation, and transpire less than unstressed plants. In most higher plants, the higher-order carbohydrates (sucrose and starch) are the principal end products of leaf



photosynthesis. Starch is formed in the chloroplasts, whereas sucrose is synthesized in the cytosol prior to export to the phloem. When K is deficient, hexose sugars (glucose and fructose) accumulate resulting in decreased levels of the high-order carbohydrates. Thus, the carbohydrate constituents of leaves at a given time represent the balance between rates of formation and rates of utilization or export (or both).

The effect of K fertilization on carbohydrate constituents of tobacco has not been studied extensively and results have not been consistent. The objectives of this investigation are:

- (1) To determine the effects of P and K fertilizer rate on growth and carbohydrate constituents of three tobacco genotypes.
- (2) To determine the effects of P and K fertilization on photosynthesis and carbohydrate partitioning between starch and sucrose.
- (3) To characterize genotype effects on the regulatory properties of ADP-glucose synthetase involved in the control of starch synthesis under varying phosphate concentrations.

#### METHODS AND MATERIALS

##### Greenhouse Experiment 1

Two tobacco types of Nicotiana tabacum L. (Burley cv. KY -14 and flue-cured cv. Speight G28) and type Nicotiana



rustica cv. B 49 were grown in pots in the greenhouse. The soil used was Zanesville silt loam (Typic Fragiudalf) that tested very low in P (5 by Mehlich III test). Phosphorus as  $\text{Ca}(\text{H}_2\text{PO}_4)_2 \cdot \text{H}_2\text{O}$  was added to burley and flue-cured genotypes at six rates (0, 134, 268, 536, 1072, and 2144 kg P ha<sup>-1</sup>), half preplant and half 4 weeks after transplanting. The Nicotiana rustica received only the preplant application. All preplant P was mixed thoroughly with the soil together with uniform applications of fine lime (3360 kg ha<sup>-1</sup>), K as  $\text{K}_2\text{SO}_4$  (560 kg K ha<sup>-1</sup>), and N as  $\text{NH}_4\text{NO}_3$  (448 kg N ha<sup>-1</sup>). Molybdenum as  $\text{Na}_2\text{MoO}_4 \cdot 2\text{H}_2\text{O}$  (1.1 kg Mo ha<sup>-1</sup>) and a fungicide (Ridomil 2 EC) were added in solution (40 ml/pot) immediately after transplanting.

Twenty cm x 20 cm fiber pots lined with plastic bags were used. Two kg washed sand was placed in the bottom of each pot, then 3 kg soil (oven dry) + fertilizer mixture were added, followed by 1 kg sand to the soil surface. Water (450 ml) was added to each pot to bring soil moisture to near field capacity and soil moisture maintained during the experiment by weighing daily and replacing water lost.

Pots were arranged on tables separately by tobacco type in a randomized split block experimental design. Treatments were replicated five times. Plants were grown to maturity and harvested at 25 days after topping (removal of terminal bud). Nicotiana rustica matured earlier than the other cultivars and was harvested 40 days after



transplanting. Burley KY 14 and Speight G28 were harvested 60 days after transplanting.

At harvest, the leaves were separated from stems and leaf area measured with a LI-3100 leaf area meter. All samples were dried in an oven at 100° for 1 hr, then at 80° for 40 hrs. Dry weights were taken and the plant material ground in a Wiley mill for analytical determinations. These included leaf total phosphorus (P), total nonstructural carbohydrates, total sugars, and starch. Photosynthetic capacity was determined on the second leaf from the apex of the plant using an oxygen electrode and conditions of saturating PPFD and CO<sub>2</sub>.

Samples of soil from each P treatment were taken after fertilization, at transplanting, and again after harvest for measurement of plant available P.

#### Greenhouse Experiment 2

Three tobacco genotypes (KY 14; Speight G28; Nicotiana rustica) were grown in pots in the greenhouse. Procedures were the same as those of Experiment 1 with exception that (a) only two rates of P were used (536 and 4288 kg P ha<sup>-1</sup>), and (b) treatments were replicated six times.

#### Greenhouse Experiment 3

Three tobacco genotypes (KY 14; Speight G28; Nicotiana rustica) were grown in pots in the greenhouse. Procedures were the same as Experiment 1 with exception that an additional rate of P (4288 kg P ha<sup>-1</sup>) was included.



### Field Experiments

An experiment was conducted in the field during two years at the University of Kentucky's Spindletop farm following cultural practices conventional for burley tobacco. KY 14 cultivar was transplanted into plots having previously been treated with varying rates and methods of application of K fertilizer. The initial soil test levels of the experimental sites were pH of 6.37, and 215 and 154 kg ha<sup>-1</sup> respectively, of P and K during 1987; and 6.65, and 240 + (P) and 190 (K) in 1988. The soil test K level was considered low and University of Kentucky Cooperative Extension Recommendations would suggest K fertilizer be added at a rate of 336 to 448 kg K<sub>2</sub>O ha<sup>-1</sup> for good production of burley tobacco. The soil pH and P levels were considered excellent for good production.

The primary thrust of the study was to look at the effects of rate of K fertilizer, hence the rates used were 0, 140, 280 and 420 kg K<sub>2</sub>O ha<sup>-1</sup>. Of secondary interest was to look at ways to increase the efficiency of fertilizer use by fertilizing varying volumes (percentages) of the soil with each rate of application. The various volume treatments were established by placing K fertilizer in bands of varying width perpendicular to the direction of the tobacco rows creating fertilized and unfertilized soil zones. These band treatments were compared with the broadcast treatments.



The treatments used are as follows:

1. Control (No K fertilizer)
2. Control (No K fertilizer)
3. Control (No K fertilizer)
4. Control (No K fertilizer)
5. 140 kg  $K_2O$  ha<sup>-1</sup>; 12.5% of soil surface fertilized
6. 140 kg  $K_2O$  ha<sup>-1</sup>; 25% of soil fertilized
7. 140 kg  $K_2O$  ha<sup>-1</sup>; 50% of soil fertilized
8. 140 kg  $K_2O$  ha<sup>-1</sup>; 100% of soil fertilized  
(broadcast)
9. 280 kg  $K_2O$  ha<sup>-1</sup>; 12.5% of soil fertilized
10. 280 kg  $K_2O$  ha<sup>-1</sup>; 25% of soil fertilized
11. 280 kg  $K_2O$  ha<sup>-1</sup>; 50% of soil fertilized
12. 280 kg  $K_2O$  ha<sup>-1</sup>; 100% of soil fertilized  
(broadcast)
13. 420 kg  $K_2O$  ha<sup>-1</sup>; 12.5% of soil fertilized
14. 420 kg  $K_2O$  ha<sup>-1</sup>; 25% of soil fertilized
15. 420 kg  $K_2O$  ha<sup>-1</sup>; 50 % of soil fertilized
16. 420 kg  $K_2O$  ha<sup>-1</sup>; 100% of soil fertilized  
(broadcast)

Five plants per plot were sampled at 40 days after transplanting for dry weight and plant K concentration measurements. Yield, price, and value data were taken after air-curing was completed. Additionally, leaves were taken from treatments 4, 8, 12, and 16 (all broadcast plots) near the topping stage of development (60 days) and



on three dates afterward at weekly intervals for measurements of photosynthesis; leaf area; dry weight; chlorophyll; concentrations of K, N, sucrose, starch; and activity of selected plant enzymes.

## RESULTS AND DISCUSSION

### Phosphorus Studies

#### Greenhouse Experiment 1

Addition of P fertilizer to soil created a range of P soil test levels (plant available P) prior to transplanting and amounts in soil followed the rate<sup>5</sup> added closely (Table 1). Amounts of P in soil at the end of the experiment differed little between the KY 14 and G28 cultivars but appeared to be slightly higher after G28 growth than KY 14. As expected amounts following these genotypes were higher than for B49 since B49 received only half as much P fertilizer as the other cultivars.



Table 1 Effect of P fertilization of Zanesville soil<sup>1</sup> and cultivar on soil test P at the beginning and end of Experiment 1.

Rate of P applied	Prior to transplanting <sup>2</sup>	B49 <sup>2</sup>	End of Expt KY 14 <sup>3</sup>	G28 <sup>3</sup>
Kg ha <sup>-1</sup>	Soil Test P, kg ha <sup>-1</sup>			
0	10	12	12	12
134	24	17	20	20
268	57	28	37	37
536	115	56	91	95
1072	256	155	256	312
2144	564	433	853	877

<sup>1</sup>Initial soil test P, pH, and exchangeable K, Ca, Mg, and Zn were, respectively, 6.0, 5.74, 119, 2016, 373, and 39.

<sup>2</sup>Values for samples having one-half each rate of P application

<sup>3</sup>Values for samples having full rate of P.

Number of leaves plant<sup>-1</sup>, leaf area, and weight of leaves, stalks, and total weight of all cultivars increased greatly with rate of P fertilization up to the fourth P rate. Further additions of P beyond the 4th rate provided only marginal increases for the B49 and G28 cultivars but somewhat larger increases for KY 14. The large response of all cultivars to P addition reflects the extremely low level of P present in the soil initially. In contrast to the plant parameters of Table 2, concentration of P in leaves and stalks of each cultivar was highest in plants grown with the 6th rate of P addition (Table 3).



Concentrations of P in plant parts at the 6th P rate ranged from 2.6 to 11.8 times greater than for plants unfertilized with P.

Table 2. The effect of P fertilization of Zanesville soil on plant characteristics of tobacco (Experiment 1).

Plant		Rate of P, kg ha <sup>-1</sup>					
Cultivar	characteristic	0	134	268	536	1072	2144
B49 <sup>1</sup>	No. of leaves plant <sup>-1</sup>	12	13	13	13	14	13
	Leaf area, Cm <sup>2</sup>	326	851	1129	1404	1610	1572
	Leaf wt., g plant <sup>-1</sup>	2	6	9	11	13	12
	Stalk wt., g plant <sup>-1</sup>	1	3	5	9	12	11
	Total wt, g plant <sup>-1</sup>	3	9	14	20	25	23
KY14	No. of leaves plant <sup>-1</sup>	7	11	13	15	17	16
	Leaf area, Cm <sup>2</sup>	587	3210	4955	6646	6946	7116
	Leaf wt., g plant <sup>-1</sup>	4	22	36	42	42	43
	Stalk wt., g plant <sup>-1</sup>	0.3	3	9	15	17	18
	Total wt, g plant <sup>-1</sup>	4	25	45	57	59	61
Speight G28	No. of leaves plant <sup>-1</sup>	6	11	13	15	16	16
	Leaf area, cm <sup>2</sup>	562	3125	4800	6360	6268	6541
	Leaf wt., g plant <sup>-1</sup>	4	25	39	58	60	61
	Stalk wt., g plant <sup>-1</sup>	0.3	4	8	18	19	20
	Total wt., g plant <sup>-1</sup>	4	29	47	76	79	81

<sup>1</sup>B49 received only one-half this rate of P fertilizer



Table 3. The effect of rate of P fertilization and tobacco type on P concentration of leaves and stalks of tobacco (Experiment 1).

Plant		Rate of P, kg ha <sup>-1</sup>					
Part	Cultivar	0	134	268	536	1072	2144
- - - - - P concentration, % - - - -							
Leaves	B49	0.06D*	0.06D	0.10CD	0.20C	0.51B	0.71A
	KY 14	0.09D	0.11CD	0.15CD	0.23C	0.54B	0.77A
	G 28	0.09C	0.12C	0.16C	0.17C	0.40B	0.61A
Stalks	B49	0.08C	0.11C	0.14C	0.28B	0.24AB	0.41A
	KY 14	0.15B	0.17B	0.17B	0.17B	0.32A	0.40A
	G 28	0.07B	0.11B	0.16B	0.14B	0.30A	0.36A

\*Rate means within a plant part and cultivar not followed by the same letter or letters are significantly different at 0.05 probability level.

Concentration of P averaged across all rates of P addition, as influenced by cultivar and plant part, are shown in Table 4. Values for B49 and KY 14 were equal in both plant parts but values for G28 appear lower than the other cultivars.



Table 4. Effect of cultivar (Tobacco type) on P concentration in leaves and stalks (Experiment 1).

Cultivar	Plant part	
	Leaves	Stalks
	P concentration, %	
B 49	0.27AB <sup>*</sup>	0.25A
KY 14	0.31A	0.23AB
G 28	0.26B	0.19B

\*Means in a column not followed by the same letter or letters are significantly different at 0.05 probability level.

#### Greenhouse Experiment 2

Plant characteristics for each cultivar grown at two levels of P are shown in Table 5. Values did not differ greatly between rates of P indicating that rate 4 was near adequate for plant growth. Although greater growth was exhibited for rate 4 in Experiment 2 than Experiment 1, the concentration of P in leaves and stalks were very similar in both experiments for rate 4. Values for P in rate 7 (Exp. 2) were much greater than for rate 6 (Exp. 1), however.



Table 5. Effect of P fertilization of Zanesville soil on plant characteristics of tobacco (Experiment 2).

Plant		Rate of P, kg ha <sup>-1</sup>	
Cultivar	characteristics	536	4288
B 49	No leaves	13	13
	Leaf area, cm <sup>2</sup>	2250	2497
	Leaf wt., g plant <sup>-1</sup>	16	19
	Stalk wt., g plant <sup>-1</sup>	15	16
	Total wt., g plant <sup>-1</sup>	31	35
	Leaf P, %	0.19	0.87
	Stalk P, %	0.33	0.30
KY 14	No. leaves	15	14
	Leaf area, cm <sup>2</sup>	10287	10166
	Leaf wt., g plant <sup>-1</sup>	74	64
	Stalk wt., g plant <sup>-1</sup>	23	23
	Total wt., g plant <sup>-1</sup>	97	87
	Leaf P, %	0.21	0.86
	Stalk P, %	0.19	0.36
G 28	No. leaves	15	15
	Leaf area, cm <sup>-2</sup>	9268	9423
	Leaf wt., g plant <sup>-1</sup>	78	73
	Stalk wt., g plant <sup>-1</sup>	26	21
	Total wt., g plant <sup>-1</sup>	104	94
	Leaf P, %	0.20	0.81
	Stalk P, %	0.22	0.91

### Greenhouse Experiment 3

Data for Experiment 3 is presented and discussed in the manuscript attached (APPENDIX A) titled "Plant Growth and Carbohydrate Partitioning in Tobacco (*Nicotiana tabacum* L.) as Influenced by Deficient to Supra-optimum Phosphorus Nutrition" by Crafts-Brandner et al. Data for various carbohydrates of Experiment 1 are also presented in that manuscript.



## Potassium Studies in the Field

Results at 40 Days

Mean plant K concentration and content, and dry weight at 40 days (averaged over years) after transplanting increased with rate of K fertilizer application up to 420 kg K ha<sup>-1</sup> (Tables 6, 7, and 8). The interaction for rate of K x percentage of soil fertilized was also statistically significant in 1988 for these parameters. Since trends existed for significant interactions in 1987, the data were combined over years for ease of discussion.

Table 6. Effect of rate and method of K fertilization on dry weight of burley tobacco at 40 days in the field (2 years).

Rate of K applied	<u>% of soil surface fertilized</u>				Mean
	12.5	25	50	100	
kg ha <sup>-1</sup>	Weight, grams plant <sup>-1</sup>				
0	32	32	32	32	32b*
140	35	36	35	35	35ab
280	32	37	38	32	35ab
420	<u>39</u>	<u>38</u>	<u>40</u>	<u>34</u>	38a
Mean	35 ab†	37a	38a	34B	

† Mean values for % of soil surface fertilized are averages of fertilized plots only.



Table 7. Effect of rate and method of K fertilization on concentration of K in burley tobacco at 40 days (2 years).

Rate of K applied  kg ha <sup>-1</sup>	<u>% of soil surface fertilized</u>				Mean
	12.5	25	50	100	
	grams K kg <sup>-1</sup>				
0	25	25	25	25	25 d <sup>**</sup>
140	32	30	30	30	30 c
280	36	35	35	36	36 b
420	<u>34</u>	<u>38</u>	<u>40</u>	<u>42</u>	39 a
Mean	34†	34	35	36	

† Mean values for % of soil surface fertilized are averages of fertilized plots only.

Table 8. Effect of rate and method of K fertilization on content of K in burley tobacco at 40 days (2 years).

Rate of K applied  kg ha <sup>-1</sup>	<u>% of soil surface fertilized</u>				Mean
	12.5	25	50	100	
	grams K plant <sup>-1</sup>				
0	0.78	0.78	0.78	0.78	0.78 d
140	1.13	1.07	1.04	1.02	1.07 c
280	1.14	1.28	1.28	1.12	1.21 b
420	<u>1.31</u>	<u>1.44</u>	<u>1.56</u>	<u>1.42</u>	1.43 a
Mean	1.19	1.26	1.29	1.19	

† Mean values for % of soil surface fertilized are averages of fertilized plots only.

These interactions suggest that greatest dry weight occurred from the higher rates of K applied on either 25 or 50% of the soil surface. Highest values for K concentration and content occurred from applying the 420K rate of 50 or 100% of the soil surface. Percentage of



surface fertilized had little effect, if any, on any measured parameter at the 140 kg K ha<sup>-1</sup> rate.

### Cured Leaf Results

Mean concentration of K and K content of cured leaf averaged over 2 years increased as rate of K fertilizer increased (Tables 9 and 10). Rate of K x % of soil surface fertilized interactions, similar to those for the 40-day datum, were found for leaf K. Highest values were found for the highest K rates in combination with the larger areas fertilized.

Table 9. Effect of rate of K and percentage of area fertilized on concentration of K in cured leaf of burley tobacco (2 years).

Rate of K kg ha <sup>-1</sup>	Area fertilized, %				Mean
	12.5	25	50	100	
	Grams K kg <sup>-1</sup>				
0	12.9	12.9	12.9	12.9	12.9 d
140	18.4	17.9	18.5	17.6	18.1 c
280	22.4	21.8	22.6	22.7	22.4 b
420	23.1	26.4	24.4	27.8	25.4 a
Mean	21.3 <sup>†</sup>	22.0	21.8	22.7	

<sup>†</sup> Mean values for % of soil surface fertilized are averages of fertilized plots only.



Table 10. Effect of rate of K and percentage of area fertilized on content of K in cured leaf of burley tobacco (2 years).

Rate of K  kg ha <sup>-1</sup>	Area fertilized,%				Mean
	12.5	25	50	100	
	Grams K plant <sup>-1</sup>				
0	2.25	2.25	2.25	2.25	2.25 d
140	3.15	3.09	3.25	3.06	3.14 c
280	3.77	3.87	4.11	4.00	3.94 b
420	<u>4.08</u>	<u>4.82</u>	<u>4.13</u>	<u>4.71</u>	4.43 a
Mean	3.67†	3.93	3.83	3.92	

† Mean values for % of soil surface fertilized are averages of fertilized plots only.

Adding K fertilizer at the rate of 140 kg ha<sup>-1</sup> increased cured leaf yield, price, and value, over the control (0 kg ha<sup>-1</sup>) as an average of two years data (Tables 11, 12, and 13). Adding higher rates of K did not result in higher values over those for the 140 kg K ha<sup>-1</sup> rate. The rate of K x % of surface soil fertilized interactions resulted in highest values for yield and value when low rates of K were broadcast (100% of surface soil). In contrast, at the highest K rate largest yield and value occurred for the 12.5 and 25% surface treatments. Cured leaf price was unaffected by % of soil surface treatments at any rate of K.



Table 11. Effect of rate of K and percentage of area fertilized on cured leaf yield of burley tobacco (2 years)

Rate of K kg ha <sup>-1</sup>	Area fertilized, %				Mean
	12.5	25	50	100	
	Yield, kg ha <sup>-1</sup>				
0	3063	3063	3063	3063	3063 b
140	3101	3129	3168	3508	3227 a
280	3060	3212	3315	3184	3193 ab
420	<u>3203</u> <sup>†</sup>	<u>3328</u>	<u>3063</u>	<u>3079</u>	3168 ab
Mean	3121	3223	3182	3257	

<sup>†</sup> Mean values for % of soil surface fertilized are averages of fertilized plots only.

Table 12. Effect of rate of K and percentage of area fertilized on cured leaf price of burley tobacco (2 years)

Rate of K kg ha <sup>-1</sup>	Area fertilized %				Mean
	12.5	25	50	100	
	\$ kg <sup>-1</sup>				
0	3.18	3.18	3.18	3.18	3.18 b
140	3.28	3.27	3.23	3.24	3.25 a
280	3.31	3.30	3.24	3.30	3.29 a
420	3.30	3.32	3.23	3.31	3.29 a
Mean	3.30 <sup>†</sup>	3.30	3.23	3.28	

<sup>†</sup> Mean values for % of soil surface fertilized are averages of fertilized plots only.



Table 13. Effect of rate of K and percentage of area fertilized on value of cured leaf of burley tobacco

Rate of K  kg ha <sup>-1</sup>	Area fertilized, %				Mean
	12.5	25	50	100	
	§ ha <sup>-1</sup>				
0	10884	10884	10884	10884	10884 b
140	11377	11444	11456	12826	11776 a
280	11352	11856	12040	11784	11758 a
420	<u>11828</u>	<u>12362</u>	<u>11111</u>	<u>11413</u>	11678 a
Mean	11519†	11887	11536	12008	

† Mean values for % of soil surface fertilized are averages of fertilized plots only.

The results of this study confirm those of limited other studies conducted at this station and are consistent with results from studies using a range of soils with various soil test K levels. In the latter study, a positive, linear relationship was found for the regression of yield difference (band treatment yield - broadcast treatment yield) on  $\text{NH}_4\text{OAc}$  extractable soil K in the range of 125 to 300 kg K ha<sup>-1</sup>. At soil test levels near 250 K, band and broadcast treatments resulted in equal yields. Below 250 K, yields were greater in broadcast than band treatments, and above 250 banding resulted in greatest yield. These results for tobacco are in sharp contrast to those commonly reported for corn which show that response to banding P and K are more likely on soils testing low with respect to the nutrient.



In the current study, soil test K was 154 and 190 kg ha<sup>-1</sup> in 1987 and 1988, respectively. From previous studies, it would have been predicted that highest yields would have resulted in the current study from broadcast applications when fertilizer K was applied at rates necessary for maximum yield. That happened at the 140 kg K ha<sup>-1</sup> rate when the fertilizer was broadcast (100% treatment). When rates of K greater than 140 kg ha<sup>-1</sup> were applied, highest yields resulted from the more narrow band treatments e.g. 12.5 and 25% of surface soil fertilized.

Reasons for these findings for tobacco are unknown but likely resulted from (a) factors affecting the efficient use of K by the plant at low soil K, and (b) from the reduction of fertilizer salt injury at high fertilizer K levels.

### Physiological and Biochemical Studies

#### Greenhouse Experiments

Maximum photosynthetic capacity (light and CO<sub>2</sub> saturated photosynthesis) of tobacco cultivars B49, KY 14 and G 28 grown under the different P regimes in Experiment 1 are shown in Table 14. In response to P rate, photosynthetic capacity measured ten days after topping increased with increasing P (Table 14). However, differences in photosynthetic capacity between the 4 and 6 P rate (536 and 2144 kg/ha) were minimal for all cultivars. This response was manifested in the final dry weight of the



plants (Table 2). Other findings for this experiment and for Experiment 3 may be found in the manuscript attached (Appendix A).

Table 14. The effect of P fertilization <sup>n</sup> of maximum photosynthetic capacity on tobacco (Experiment 1).

Cultivar	Rate of P, kg ha <sup>-1</sup>					
	0	134	268	536	1072	2144
Photosynthetic Capacity, $\mu\text{mol m}^{-2} \text{s}^{-1}$						
B49	9.8	28.8	32.8	45.2	47.9	46.6
K14	8.0	17.9	23.2	27.8	30.5	30.5
G28	16.6	34.0	39.5	42.3	42.3	45.3

#### Field Experiment

A detailed study of leaf growth and carbohydrate partitioning was conducted on the field K experiment. Leaf samples (second or third leaf from the apex) were taken at weekly intervals after topping on the 0, 140, 280, and 420 kg ha<sup>-1</sup> broadcast K plots. Statistical analysis has not yet been completed on the data, but tables of means have been compiled. Leaf K levels are indicated in Table 15. The general K concentrations for the treatments were 0 K < 140 K < 280 K = 420 K.



Table 15. Leaf K concentration at various K fertility levels

K fertility	Days after topping			
	5	14	19	27
kg ha <sup>-1</sup>	- - - - -mg K/g dry wt - - - - -			
0	9.6	14.2	10.6	10.3
140	12.4	14.0	14.4	13.1
280	14.7	17.2	16.1	17.2
420	15.9	19.1	20.1	17.1

Leaf growth, as indicated by dry matter accumulations and leaf expansion (Tables 16 and 17), followed the same trends as leaf K level. Thus, leaf growth appeared to be maximized at the 280 K broadcast treatment.

Table 16. Leaf dry matter at various K fertility levels

K fertility	Days after topping			
	5	14	19	27
kg <sup>-1</sup>	- - - - -g dry wt/leaf- - - - -			
0	2.7	4.1	6.1	7.2
140	3.5	6.8	8.2	8.7
280	5.2	6.6	9.8	9.6
420	4.9	8.2	9.7	9.0



Table 17. Leaf area at various K fertility levels

K fertility	Days after topping			
	5	14	19	27
kg ha <sup>-1</sup>	- - - - -cm <sup>2</sup> /leaf- - - - -			
0	659	755	930	1043
140	728	1092	1220	1400
280	1061	1153	1480	1412
420	966	1311	1471	1468

Partitioning of nonstructural carbohydrates was not markedly influenced by the K fertility treatments as indicated by the levels of sucrose and starch in freeze-dried tissue (Tables 18 and 19). Sucrose levels remained relatively constant over the sampling times where as starch decreased to a low level by the final sampling time.

Table 18. Sucrose concentration at various K fertility levels.

K fertility	Days after topping			
	5	14	19	27
kg ha <sup>-1</sup>	- - - - -mg/g dry wt- - - - -			
0	61	42	76	54
140	64	56	97	69
280	67	48	71	55
420	68	49	78	56



Table 19. Starch concentration at various K fertility levels.

K fertility kg ha <sup>-1</sup>	Days after topping			
	5	14	19	27
	- - - - -mg/g dry wt- - - - -			
0	43	35	46	18
140	50	121	82	32
280	64	52	49	10
420	81	52	30	12

Even though the sucrose levels were not different for the K fertility treatments, the activity of the rate limiting enzyme in sucrose biosynthesis, sucrose phosphate synthase (SPS) Table 20), was influenced by K treatments in a manner similar to leaf growth. In addition, the activity of the rate limiting enzyme in CO<sub>2</sub> fixation, rubisco, was affected by K level (Table 21). For both enzymes, the activities were 0 K < 140 K < 280 K = 420 K.



Table 20. Sucrose phosphate synthase activity at various K fertility levels.

K fertility	Days after topping			
	5	14	19	27
kg ha <sup>-1</sup>	- - - - - $\mu\text{mol}/\text{dm}^2\cdot\text{h}$ - - - - -			
0	12	3	23	3
140	22	31	41	68
280	23	48	76	77
420	20	38	86	44

Table 21. Rubisco activity at various K fertility levels.

K fertility	Days after topping			
	5	14	19	27
kg ha <sup>-1</sup>	- - - - - $\mu\text{mol}/\text{m}^2\cdot\text{s}$ - - - - -			
0	38	26	49	32
140	40	42	61	53
280	27	48	81	96
420	34	43	111	62

It was interesting to note that while rubisco activity decreased at low K levels, the rubisco content per unit leaf area (determined by immunological procedures) was similar for all K levels (Table 22). This result was consistent with leaf N total concentration which was not markedly influenced by K fertility level (Table 23). Thus,



it may be tentatively concluded that low leaf K had an effect on the activation state of rubisco.

Table 22. Rubisco content at various K fertility levels

K fertility	Days after topping			
	5	14	19	27
kg ha <sup>-1</sup>	- - - - - mg/dm <sup>2</sup> - - - - -			
0	45	52	52	40
140	42	39	43	35
280	51	47	59	52
420	48	55	59	33

Table 23. Total N concentration at various K fertility levels.

K fertility	Days after topping			
	5	14	19	27
kg ha <sup>-1</sup>	- - - - - mg/g dry wt- - - - -			
0	64	58	54	52
140	59	48	50	49
280	56	54	52	52
420	55	53	54	51

It may be seen from the above that the effect of the treatment is to increase the yield of the product.

Table 22

Yield of product

kg ha<sup>-1</sup>

0

100

200

300

Table 23

Yield of product

kg ha<sup>-1</sup>

0

100

200

300

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